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Quasars in Normal-Looking Galaxies

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Quasars in Normal-Looking Galaxies

Quasars are intensely luminous, bidirectional beacons of light produced and powered by supermassive black holes at the center of galaxies. Galactic material such as gas, dust, and even stars, if located too close to a black hole, will succumb to its relentless gravitational force and are pulled inside. During this process, the infalling material stretches, heats, and accelerates, creating a relativistic playground of enormous forces near the *event horizon*, the point of no return from the black hole's pull. These forces produce powerful, twisting magnetic fields; electrical currents; and strong radiation across the spectrum from gamma rays to radio waves.

Astronomers refer to the ingestion of material by a black hole as an *accretion episode*. If sufficient material is involved, these episodes result in a galactic nucleus that radiates strongly in all directions. Over time, with additional episodes, the energy level rises sufficiently to create a twin-lobed quasar. At this point, the combined effect of the quasar's jets and intense radiation push material from the environment of the black hole, terminating the quasar phenomenon and leaving the galactic center quiet until another accretion episode occurs.

It follows, then, that galaxies with black holes that contain abundant gas and dust—ones which also produce lots of stars—are good candidates for quasar formation, especially if more than one galaxy is involved. Indeed, computer simulations of the merger of two ultra-luminous starburst galaxies indicate that they will eventually produce powerful quasars. Initially, light from the beaming quasar would be partially blocked by the material of the merging galaxies, but, over time, would become more visible as the galaxies morphed into a single, more spherically shaped object.

To confirm this theoretical picture and better understand its details, a group of astronomers, led by Swiss astronomer Kevin Schawinski, studied a population of faint, dust-obscured quasars. They reasoned that the diminished light received from the quasar jets would make details in their host galaxies more visible. Additionally, computer simulations of galactic mergers

This artist's concept shows a developing quasar at the center of a galaxy. The dusty, doughnut-shaped cloud of gas feeds a massive black hole at the galaxy's center. As the black hole takes on material, brilliant radiation over many wavelengths, particularly X-rays, is produced just outside the black hole. Eventually twin, but oppositely directed, lobes of energetic particles and radiation (a quasar) form that can be seen across much of the universe.

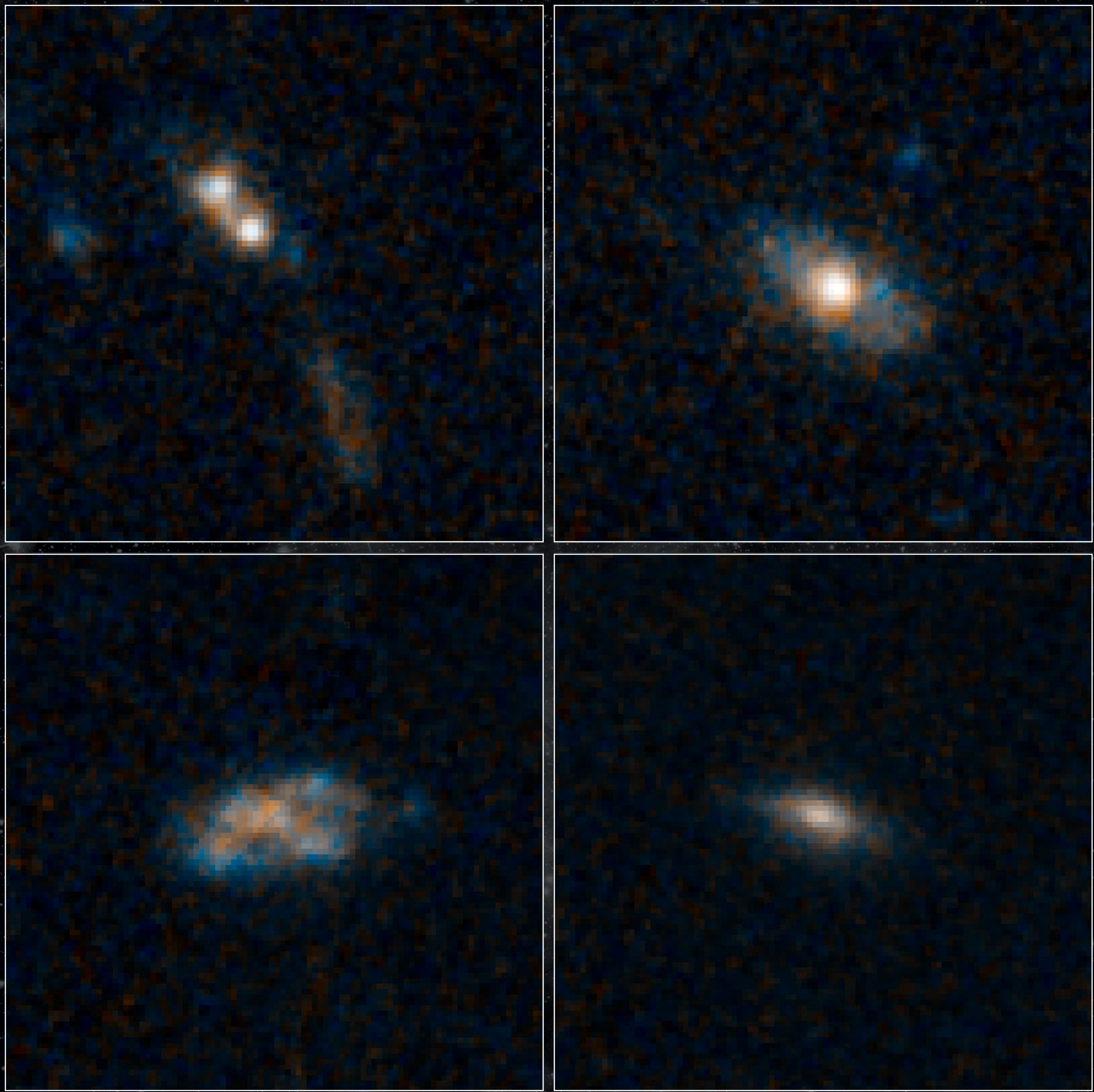
Of the 30 galaxies evaluated by the team, only galaxy 29263 has a shape that is indicative of a major merger.

indicated that the phase of maximum obscuration coincides well with the phase of peak morphological disturbance. The scientists expected that this coupling would make the dynamics of mergers easier to see and study.

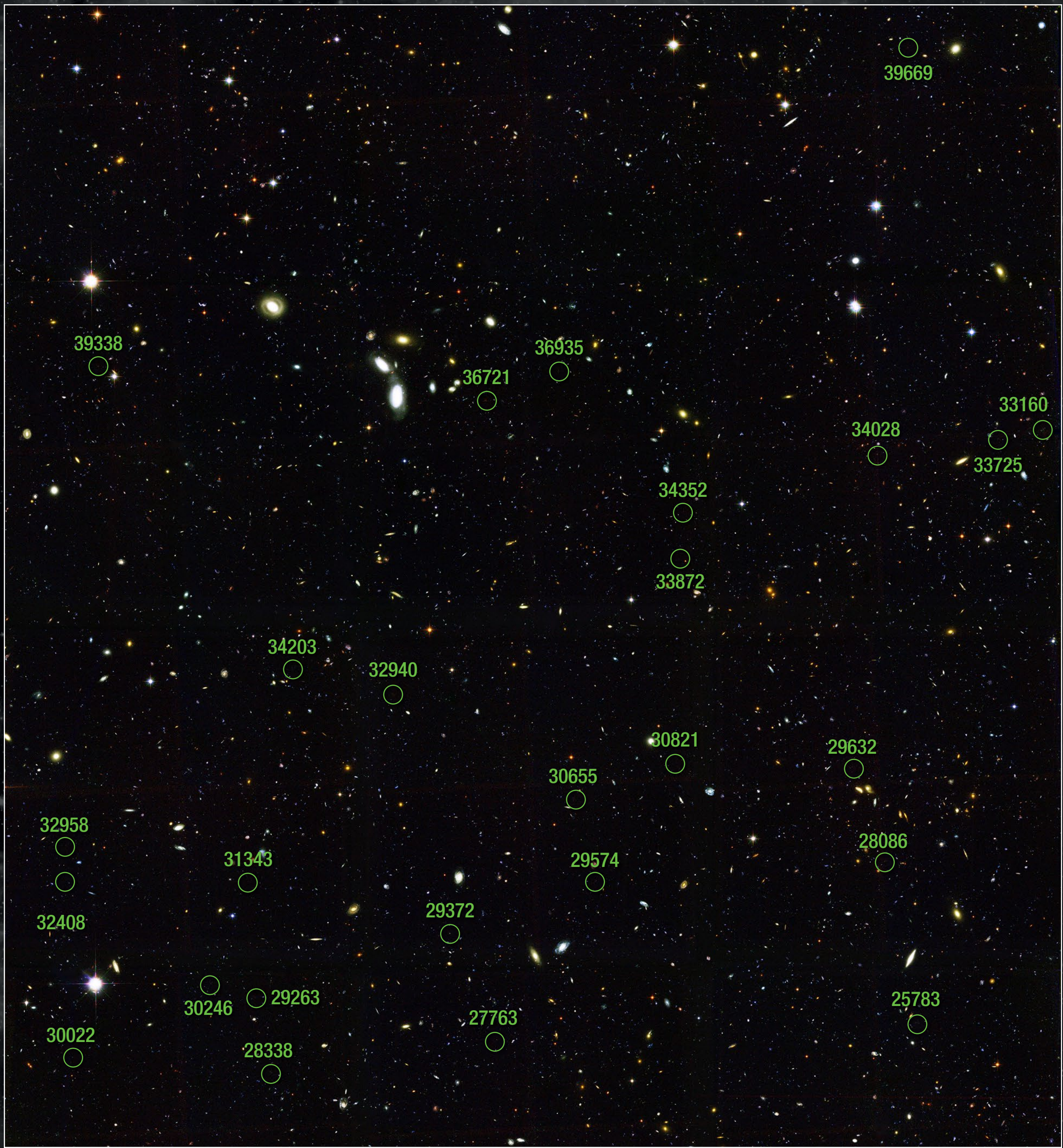
A census of 30 quasar host galaxies was conducted using data from *Hubble* and the infrared-sensitive *Spitzer Space Telescope*. The observations were part of the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS), one of *Hubble*'s Multi-Cycle Treasury programs. This survey detected faint galaxies in the range of 8 billion to 12 billion light-years distant, a time in cosmic history believed to be important for growing large black holes.

The CANDELS images contained many more than these 30 galaxies; the particular ones chosen for analysis appeared extremely bright in corresponding *Spitzer* images. This was a telltale sign to astronomers that significant material is falling into their central black holes and that dust is absorbing the visible light emitted by the material. The masses of the chosen galaxies range somewhat in size, but all are approximately the same as our Milky Way galaxy.

The team carefully analyzed the galaxies' shapes using the near-infrared channel of *Hubble*'s Wide Field Camera 3 (WFC3). Near-infrared light can penetrate areas of gas and dust and expose details that are blocked at visible-light wavelengths. Of the 30 galaxies examined, two were too dim to analyze accurately. Three of the remaining 28 showed faint galaxies nearby the targeted galaxies, but with no clear indication that they were interacting. Only one galaxy in the sample showed actual evidence of a galactic encounter.



Shown enlarged are four galaxies from the survey. Only galaxy 29263 (upper left), with its double nucleus, manifests clear evidence of engagement with a companion galaxy. A faint blue and brown streamer appears below the merging systems. The blue patches are star-forming regions; the brown areas are either dust or old stars.



This image shows the positions of 26 of the 30 quasars examined in the Schawinski team's study. The area of the sky where these quasars reside is called the Great Observatories Origins Deep Survey (GOODS) South field, located in the direction of the southern constellation Fornax. Four of the study's quasars fell outside the cropped edges of this Hubble *image.*

As an additional check, Schawinski's team selected images of other galaxy interactions taken with *Hubble*'s Advanced Camera for Surveys, modified their pixel size, matched the background noise to WFC3 data, and performed additional data processing steps to determine whether features in known mergers could be detected in their 30 survey targets. This exercise showed the team that—while tidal tails and other delicate deformations can disappear from view in galaxies like the survey targets—the irregular, multicomponent nature of major mergers would remain visible.

The team's findings bolstered evidence from other studies showing that the growth of most massive black holes in the early universe was fueled by numerous small events over longer periods of time rather than by a small number of short-term, major events, such as major galaxy mergers. At earlier epochs in cosmic history, the universe was smaller and generally thought to be filled with many more dwarf galaxies than seen today. Mergers between these smaller systems could fuel the growth of massive galactic black holes and spawn quasars without disturbing the morphology of their host galaxies.

Further Reading

Grogin, N. A., et al. "CANDELS: The Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey." *The Astrophysical Journal Supplement Series* 197, no. 35 (December 2011), doi: 10.1088/0067-0049/197/2/35.

Schawinski, K., et al. "Heavily Obscured Quasar Host Galaxies at $z \sim 2$ Are Discs, Not Major Mergers." *Monthly Notices of the Royal Astronomical Society Letters* 425 (2012): L61–L65.

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Treister, E., et al. "Heavily Obscured AGN in Star-Forming Galaxies at $z \simeq 2$." *The Astrophysical Journal* 706 (November 20, 2009): 535–552.

Volonteri, M. "The Formation and Evolution of Massive Black Holes." *Science* 337, no. 6094 (August 3, 2012): 544–547.

Dr. Kevin Schawinski was born in Zurich, Switzerland, and grew up in the countries of Switzerland and Germany. He is currently professor of galaxy and black-hole astrophysics at Eidgenössische Technische Hochschule Zurich (the Swiss Federal Institute of Technology Zurich) and co-founder of the Galaxy Zoo, an online citizen science project that has engaged more than half a million people in scientific research. His research focuses on understanding the effect of black-hole growth on the formation and evolution of galaxies and discovering the ultimate origin of supermassive black holes in the universe. Dr. Schawinski completed his doctorate in astrophysics in three years at Oxford University, for which he won the Royal Astronomical Society's thesis prize. He then moved to Yale University where he worked as a NASA Einstein fellow before returning to Switzerland.